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Effects of Peer Network Interactions on Adolescent Cannabis Use

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Abstract

Purpose: This study capitalises on three waves of longitudinal data from a cohort of 4351 secondary school pupils to examine the effects on individuals' cannabis use uptake of both peer cannabis use and position within a peer network.

Methodology: Both cross-sectional and individual fixed effects models are used to estimate the effect on cannabis use of nominated friends' cannabis use, of reciprocity and transitivity of nominations across the friendship cluster, and of interactions between these nominated friends. Post hoc analyses parsed the behaviour of reciprocating and non-reciprocating friends.

Findings: Cannabis use varied depending on the stability of friendship network and the degree of reciprocity and interconnectedness within the group. Behavioural influence was strong, but interaction effects were observed between the prevalence of cannabis use among friends, the structure of the friendship group and ego's proximity to group members. These interactions demonstrate that behavioural influence is more salient in more cohesive groups. When reciprocating and non-reciprocating friends' mean cannabis use were separated, influence from reciprocating friends was estimated at twice the magnitude of other friends.

Originality and value: While preventing of any one individual from using cannabis is likely to have a multiplier effect on classmates, the bonds and interactions between classmates will determine which classmates are affected by this multiplier and the salience of that effect.

Keywords: Peer Influence; Adolescent Cannabis Use; Social Network Analysis; Reciprocity; Interaction Effects

Introduction

Drug use is an interesting category of human behaviour for a variety of reasons. In spite of concerns about the risks to public health from certain drugs and resulting strict legal controls, many individuals succeed in obtaining, using and enjoying these substances. Individuals who are initiated into use of intoxicating and illicit substances usually undergo this initiation during their teenage years (Van Ours and Williams, 2009). Lifetime experience of drug use prevalence among 11-15 year-olds in the United Kingdom has been estimated at 22%, with cannabis shown to be the most widely available and enduringly popular of these substances (Health and Social Care Information Centre 2011; Miller and Plant, 2002). Persistent early adolescent cannabis use may have grave implications for long-term mental health and psychosocial outcomes (Patton et al., 2002; Kuepper et al., 2011). Additionally, some authors have argued that some “soft” drugs, including cannabis, function as "gateways" into use of more expensive and addictive drugs later on (DuPont, 1985; Kandel and Jessor 2002). Therefore, improved understanding of the circumstances and the intrinsically social context in which individuals decide to first experiment with cannabis could be immensely valuable, particularly if such an account lends itself to using observable risk factors to trigger timely interventions.

This paper describes an attempt to produce a model of early adolescents’ behavioural responsiveness to both peer network structure and the prevalence of cannabis use among their friends. It avails of a uniquely amenable dataset, containing multiple waves of data on both network structure and cannabis use behaviour, namely the Belfast Youth Development Study (BYDS). It provides evidence that, between ages 12 and 15, cannabis use was more likely among cohort members whose nominated friends represented a less cohesive unit and who were less central to their friendship cluster. Prevalence of cannabis among friends appears to exert a strong influence on participant cannabis use, though the salience of this influence depends on whether friendship is reciprocated by both parties.

Literature

A wide range of estimates and opinions are available as to the extent to which an individual's drug use behaviour is influenced by the drug use behaviour of his or her peers and by the interactions which take place within the peer group. While significant innovation has taken place over several decades to allow this question to be addressed more satisfactorily, progress has been neither linear nor cumulative. For example, consider two distinct areas of progress from the Health Sciences and Economics respectively.

Social network parameters and structural peer effects

Individuals' decision-making is often situated within their social groups. The use of social network data allows for close examination of the parameters of the social networks in which such decisions are made. We can distinguish, for example, the influence mutually-reciprocating friends from that of other peers (Krackhardt and Kilduff, 1999; Vaquera and Kao, 2008; Veenstra et al. 2013). By aggregating the nominations of various members of a clique or friendship cluster, a sociogram of the network can be drawn up and individuals assigned to positions relative to the "centre" of this cluster (e.g. Pearson and Michell, 2000; Ennett and Bauman, 1993). This assigned position is then used to predict likelihood of various behaviours, including drug use.

This approach has yielded a variety of conclusions. Ennett and Bauman (1993) found that social isolates, those who report few ties and whose cluster membership is not acknowledged by their peers, were more likely to take up smoking. Contrary findings have since suggested that the at-risk group reside between network centrality and isolation. "Liaisons" and "peripherals" are among the names given to individuals whose network position at the periphery of a single, or multiple clusters, i.e. where ties are with some but not all members of one or more groups. These individuals, who neither enjoy secure membership within one cluster, nor fall outside of all clusters in the network, have been identified as more likely to use both legal and illegal drugs (Abel et al., 2002; Henry and Kobus 2007). Being in a leadership or high status position in a cluster has also been suggested as a

risk factor for substance use¹ (Ennett et al., 2006; Lansford et al., 2009a). Taking the evidence together, there seem to be risks associated with any network position².

This paper argues that this approach to network analysis makes an overbearing assumption that a small number of categories of position exist. Given the idiosyncrasy of human relationships, it seems the introduction of arbitrary cut-offs between centrality, isolation and those in between may be too blunt of an approach. Given that the parameters of reciprocity and transitivity which underlie the assignment to network positions are surely continuous and fluid, applying such cut-offs will inevitably categorise two individuals who are close together on these distributions to distinct categories. By explicitly modelling these parameters on a continuous scale and allowing for curvature in their relationship with drug use outcomes, the current study seeks a more parsimonious iteration of this line of inquiry.

Behavioural peer effects and endogenous interactions

A second and distinct type of peer effect has been the focus of the behavioural economics literature: the effect on the drug use of one individual (ego) had by the drug use of alter, ego's peer (also called "endogenous interactions"). However, several identification problems obstruct credible estimates of this effect (c.f. Manski, 1993). Upward bias accrues from several sources. Peers are exposed to similar background factors which are also correlated with drug use. Individuals also respond to characteristics other than behaviours and select friends on the basis both of similarity of characteristics and of behaviour. Economists have responded to Manski's challenges over two decades with concerted efforts towards finding appropriate data and developing appropriate statistical approaches to producing unbiased estimates.

This literature is dominated by cross-sectional studies which use mean group drug use at the level of the school, school grade or neighbourhood to estimate peer effects. In this context, the most

¹ This leadership construct is distinguished in a study of Lansford and colleagues (Lansford et al., 2009b) from having a central and secure position within the network or cluster.

² Henry and Kobus offer a useful discussion of possible methodological sources of discrepancy (2007).

credible models of the peer effect on a young person's drug use employ either fixed effects at the school level (Gaviria and Raphael, 2001), fixed effects at the level of the neighbourhood (Case and Katz, 1991), or instrumental variables whereby peer drug use and ego's drug use are estimated simultaneously³.

The reliance in the economics literature on assumed peer interactions and network ties within a common school or address owes in part to conventions of data collection. Information on friendships and ties were not, until recently, conventionally collected within economics (Manski 2000). However, the availability of datasets such as the Add-Health (c.f. Clark and Lohéac, 2007) and ESPAD (c.f. McVicar, 2011) has enabled the location of peer effects using reference groups where interactions are not wholly assumed, i.e. nominated friends.

Confluence of interests

Until recently, these distinct sub-disciplines pursued different questions as outlined. However, it is increasingly clear these questions cannot be considered wholly in isolation from one another. The questions can be viewed as complimentary: if the association between friends' behaviour and ego's is causal, the association should be stronger where relationships are more intense and clusters more cohesive (Oetting and Beauvais, 1987; Vásquez, 2010). One reason for this is the two-versus one scenario raised by Kobus and Henry (2010). They argue (with due attribution to Simmel and Wolff, (1950), that a defining feature of tightly-knit clusters is the occurrence of triads, groups of three people where each has a friendship with the other two. This makes the individual more susceptible to influence, because they are placed in a two-versus-one situation. It follows that influence would be less salient if a person's two drug-using friends had no relationship with one another, as the two-versus-one scenario would not arise. Similarly, it seems likely that the effect on drug use of network

³ In this context, an instrumental variable must predict peer drug use but must also be validly omitted from the model for ego's drug use. Examples include mean grade point average background characteristics (Gaviria and Raphael, 2001) and neighbourhood-level socioeconomic indicators (Evans et al., 1992). Because these characteristics will often be functionally related to the peer status of ego and alter, their omission from the model for ego's drug use is difficult to defend.

position relative to a friendship cluster will vary depending on the prevalence of drug use in the cluster.

Furthermore, the theoretical underpinnings of the network structure literature may help to address how behavioural effects might work. Consider, for example, the *Strength of Weak Ties* account of normative diffusion provided by Granovetter (1973, 1983). A person with a strong tie to a group, under Granovetter's formulation, has consistent, emotionally intense and reciprocal relationships with other group members. A person with weak ties to the group (or multiple groups) either has less consistent or intense relationships with group members, or has consistent and intense relationships with only *some* group members. Granovetter argues that weak ties are important agents within the network. Because they are not strongly attached to a single group, they will likely move between groups, forming ties at the periphery in an effort to gain full group acceptance and membership. In the process of moving between groups, these individuals carry information about overall norms which would not transfer between groups if all network members were firmly attached and embedded in one group.

Considering drug use, the corollary of this theory is that clusters which are internally cohesive to the point of being exclusive, and, hence, have no weak ties *and are without any drug using members to begin with*, will be protected and insulated from countervailing norms around drug use. This account suggests drug use uptake may be most likely for those with a mix of strong and weak ties and that there is curvature in the association between cluster interconnectedness and drug use. This mix of strong and weak ties best describes the "liaisons" described as at risk by Henry and Kobus (2007).

This hypothesis appears initially to be contradictory of the intensity hypothesis and of Peer Cluster Theory (Oetting and Beauvais, 1987), which posit that individuals are more responsive to friends with whom they share more intense bonds. In fact, the two are compatible and can be thought of as complimentary. In essence, Granovetter's construct suggests how, on a group level, drug use can initially penetrate the borders of a peer cluster. The intensity hypothesis then predicts how

individual cluster members will respond to drug use within their cluster, based on the structure of that cluster.

Again, a line can be drawn between this account and theoretical writing in Economics. Becker's model of interaction effects (1974) described how the normal utility formula for an individual's consumption of a given is *augmented* by the personal cost of being at a different level of consumption to peers. Extending this analysis, the individual has more to lose from having their behaviour differ from a reciprocating friend than they do from a non-reciprocating one: a closely-held friendship is potentially at stake if the individual does not conform.

Towards a parsimonious approach

Few empirical social network-oriented studies directly account for the effect of peers' outcomes alongside network position, two exceptions being those of Ennett and colleagues (2006) and Kobus and Henry (2010). Ennett and colleagues found three measures of social proximity to cannabis, alcohol and cigarette use all to be significant predictors of ego's own use, while also finding high social status and social isolation to predict use of alcohol and cannabis use. Kobus and Henry (2010) reported significant interaction effects between network position and peer influence. Peer effects for cigarette use were stronger for those in a central or isolated position, whereas the opposite was found for cannabis, for which peer effects were strongest for liaisons.

The ability to address the extents both of behavioural and relational peer effects hinges on the availability of data which describe ties within the network. The resource in most scant supply has been longitudinal data charting change in both cluster membership composition and behaviour across the cluster. The current study avails of one of the rare datasets containing such longitudinal information. Thus, its aim is twofold: to test the robustness of peer effects previously evidenced by cross-sectional studies; and to harness the aforementioned innovations in order to speak simultaneously to the importance both of peers' behaviour and of peer group structure.

Hypotheses

This study retests the intensity hypothesis and the findings of Vasquez (2010), that the influence of peers increases in strength where peer interactions with the individual are more regular, intense and intimate. It is also hypothesised that a *curvilinear* relationship exists between drug use and indicators of network position and cluster density. Though network position is operationalised differently, this second hypothesis flows directly from the finding of Henry and Kobus (2007) that drug use uptake is most likely among those whose proximity to a friendship cluster lies between the extremes of network centrality and isolation. This second hypothesis also serves to test whether “weak ties” and cluster openness aid the transmission of norms (Granovetter, 1973; 1983), or indeed the actual exchange of drugs.

Methods

The current study avails of data from three consecutive waves of the Belfast Youth Development Study (BYDS). This is an ongoing survey-based longitudinal study of young people who attended one of 42 schools across Belfast and two nearby towns in Northern Ireland. Entry point to the current study is the second wave, collected in 2001/2002 when participants were aged between 12 and 13. Ethical approval for data collection was obtained from the Ethics Committee of the Queen’s University Belfast School of Sociology. Participants were fully informed of the nature and purpose of the study and their consent assumed by their agreement to complete the questionnaire. Participants’ parents could also withdraw consent for participation ahead of the data collection. 5371 individuals completed a survey in at least one of the five waves, representing over 74% of pupils in the participating schools.

Analytical variables and measures

Cannabis use was measured within an array of self-report items pertaining to drug use experience in several categories. The outcome in the current study is a positive response to an item asking pupils if they had used cannabis in the previous 12 months. The prevalence of positive responses to this item

was 17.72%, 28.37% and 36.65% respectively in years 2, 3 and 4. The dataset also contains an array of explanatory variables associated in the literature with intoxicant use, including sex, age, household structure, socioeconomic status and engagement with education. The specification of these variables for use as controls is described in the Supplementary Appendix.

Surveys in each wave included an identical field asking each pupil to name up to 10 individuals from their year group whom they considered friends or liked to spend time with⁴. Respondents nominated a mean of 7.35 friends (SD = 2.71). The mean number of nominated friends who also provided a valid response to the wave 3 survey was 6.58 (SD = 2.62). Identification of these nominated individuals allowed for cannabis use prevalence among identified friends to be derived and also for the structure of the friendship cluster to be explored.

The samples used in the current study are restricted to those with valid responses on the aforementioned cannabis question and to individuals who name at least two friends, as this is required to obtain valid transitivity scores. Wave 3 cross-sectional results are based on a sample of 4,206 participants. Longitudinal analysis is conducted on two available panels: those satisfying the above criteria in at least two of waves 2, 3 and 4 (N = 4213), and those satisfying the criteria in all three waves (N = 2707)⁵.

Parameters of network and cluster structure

Reciprocity

This is the rate at which ego's nominated friends nominate them reciprocally. This was calculated by counting the number of friends who nominated ego in return, and dividing this number by the total number of friends who also responded in the same wave.

Transitivity and Convergence

⁴ Respondents were asked to write the name of their best friend and asked to use the following nine spaces to answer the following question: "Who else in (your Year) in this school are you friendly with, or hang about with.

⁵ As no substantial differences were found between the two panels, results from the larger unbalanced panel are reported here exclusively.

Whereas the reciprocity index reflects the extent to which ego's friendship is accepted by her cluster of friends, transitivity and convergence reflect the extent of interconnectedness among the group ego has identified as her friends. The specific role of these two indices is to reflect whether the friends identified collectively *function* as a group of friends, or comprise separate friendships or subgroups.

Transitivity refers to the existence of friendship triads involving ego and is calculated as the proportion of ego's friends' nominations which are given to another of ego's friends (formula provided in Supplementary Appendix). In descriptive terms, the denominator is the total number of friends nominated by ego who also completed the survey. The numerator is the sum of the proportions of ego's friends' friends who are also among ego's friends, minus the number of times ego herself is nominated by a friend.

A further "convergence" index is generated to reflect the cohesion and intra-cluster reciprocity among nominated friends. This variable is described in depth in the Supplementary Appendix.

Turnover

In models which use multiple waves, this index is used to take account of the role of homophilic selection processes. It reflects the proportion of a person's friends in year *Y* who were not nominated as friends in the previous year *Y-1*.

Indegrees

This index is adapted from the SIENA platform (Ripley, Snijders 2010). In the current study, the term refers to the number of individuals outside of ego's nominated cluster who nominate ego. It serves as a further surrogate for popularity and possible network interactions and ties beyond the immediate boundaries of friends.

Empirical Modelling and Statistical Analysis

This paper focuses both on main effect estimates of the associations between cannabis use likelihood and the various predictors outlined above, including friends' cannabis use and network parameters; and on interactions between those predictor variables within reduced-form models of responsiveness to peer interactions and behaviour. All data for the current study were coded and analysed using Stata (V. 13). Conventional regression estimators are used so that the results can be easily interpreted by researchers from across multiple fields⁶.

Models specifications are first explored in a cross-sectional Ordinary Least Squares regression (OLS), using data from wave 3 of BYDS⁷. The model adjusts for correlated effects using dummy variables representing the school the individual attended. In addition to the aforementioned network parameters, the square of each term is also included in multiple iterations of the model, allowing for a test of whether a curvilinear relationship exists between these indices and likelihood of cannabis use.

(Insert Figure 1 about here)

In order to minimise any upward bias in estimates owing to reverse causality (whereby ego's behaviour is influencing friends' behaviour and/or the shape of her network), models are re-tested using a fixed effects model, constructed using waves 2 through 4 of BYDS. This model effectively expresses change in the cannabis use outcome as a function of change in the predictors. Explanatory variables included in the model are restricted to those which can vary within the period of the study, such as household structure. Stable characteristics such as gender can be validly omitted, assuming the effects of these characteristics are fixed, i.e., already captured in the baseline value of the individual's behaviour.

6 As the central unit under investigation was each individual's egocentric network, rather than the whole school group network, it was not necessary to impose exclusion criteria to schools based on levels of missingness, as might be the case using SIENA (Veenstra et al., 2013).

7 OLS has been a standard estimator in the peer effects literature (McVicar, 2011). A coefficient of 0.1 is usually indicates that a 10% increase in peers' drug use is associated with a 1% increase in ego's likelihood of use. OLS coefficients are more easily comparable with Fixed Effects and Two-Stage Least Squares, two conventional approaches to eliminating various sources of bias.

Results

Main effects

Cluster parameters

Indices pertaining to cluster structure and ego's proximity to the cluster are shown to be associated with likelihood of cannabis use, though the magnitude and sign of these effects vary depending on the specification of the model. In the cross-sectional model, greater reciprocity from nominated friends appears to be positively associated with greater likelihood of cannabis use (Table 1).

This coefficient is over twice the magnitude in model A4 than in A1, with the inclusion of the transitivity index and over four times the magnitude in B4 with cannabis prevalence and transitivity both included, suggesting multiple interaction effects, which are further discussed in the ensuing section.

Transitivity is negatively associated with likelihood of cannabis use in all models. In model B4 (Table 1), an additional 10% transitivity among friends is estimated as associated with being at 1.4% lower risk of cannabis use. This suggests that the more agreement there is among an individual's friends on the membership composition of a group or cluster, the less likely that the individual has used cannabis. Cannabis users are found to identify with more open, diffuse, less interconnected and cohesive groups. Note, however, that Fixed Effects estimators of main effects (Table 3: D0-D2) put the magnitude of this effect much lower than the cross-sectional model, with the coefficient dropping to -0.047 in model D0. This suggests a possible simultaneity bias in cross-sectional models: ego's cannabis use may be influenced by the structure of her network, but may also influence the type of friendship networks which she joins, with the suggestion that friendship cohesion may be a lower priority for cannabis users than for non-users.

No independent effect of convergence is found in any model; hence we only report the relevant coefficients in Tables 1. This suggests that, while the possibility exists that equivalent transitivity

scores may represent differently shaped clusters, this variation is not sufficiently high as to affect the coefficient for transitivity. Additionally, no curvilinear effect is apparent for either the transitivity or convergence indices⁸, suggesting no evidence for the idea conveyed in hypothesis 2 that “weak ties” are required for pro-cannabis norms to be diffused to members of a cluster, or for trade and experimentation with cannabis to take place.

In all models, coefficients for indegrees were small, positive and statistically significant. In OLS models, coefficients were all ~ 0.015 (SD = 0.005), suggesting that receiving an additional 10% of nominations from outside named friends is associated with 1.5% additional likelihood of cannabis use. This coefficient diminishes to 0.005 (SD = 0.002) in fixed effects models, suggesting some of the cross-sectional coefficient may be biased by reverse causality, whereby cannabis use affects popularity rather than vice versa.

(INSERT TABLE 1 ABOUT HERE)

Friendship “turnover”

Lower continuity in friendship nomination is strongly associated with greater likelihood of cannabis use (D1-D5; Table 3). This supports the idea of drug use taking place against a backdrop of network instability. As discussed in the context of transitivity, social churn may be a condition which exposes an individual to more behavioural possibilities and normative influences.

Friends’ cannabis use

The main effect for friends’ cannabis use is estimated at a range of values. In all cases, the coefficient is positive, indicating that, as shown throughout the literature, ego is more likely to have used cannabis where a greater proportion of ego’s friends have used cannabis. The magnitude of coefficients are lower in fixed effects models (~ 0.35 ; Table 3- D1) than in cross-sectional models

⁸ No curvilinear effects were suggested by the inclusion into the model the square of any of the cluster parameters. Results are not shown in the interest of conserving space, but are available on request.

(~0.6; Table 1- B4), suggesting that that fixed effects models are successful in removing some of the simultaneity bias which causes cross-sectional associations.

Interaction effects

There is some evidence of an interaction effect between reciprocity and transitivity, born out in both cross-sectional models (Table 2- C0) and fixed effects (Table 3- D2). This indicates that the negative association between lower transitivity and greater likelihood of cannabis use partly captures an association between reciprocity and cannabis use.

In the case of reciprocity, strong interactions with both transitivity and friends' cannabis use are key to understanding how it affects cannabis use, as reciprocity coefficients are non-significant where those variables are omitted. Taken together, the results indicate that the association between reciprocity and an individual's cannabis use probably captures influence from those reciprocating friends. Furthermore, the interaction terms in Table 2 (C2-C4) and Table 3 (D2-D5) suggest that the peer effect of friends' cannabis use is greater where friends have reciprocated ego's nomination, supporting the intensity hypothesis.

There is little clear evidence of an interaction effect between cannabis use prevalence and transitivity of nominations among ego's nominated friends. Where interaction coefficients appear in cross-sectional models (Table 2- C3) suggest that cannabis use prevalence is more salient at lower levels of transitivity, so long as the *reciprocity X friends' cannabis prevalence* interaction is already adjusted for. Results were inconclusive as to the existence of a three-way interaction between reciprocity, transitivity and peer behaviour, though the positive sign on this interaction term in the cross-sectional model suggests that friends' use is more influential where both reciprocity and transitivity are high.

(INSERT TABLE 2 ABOUT HERE)

Clear also is the evidence for a positive interaction effect between friendship turnover and cannabis prevalence among friends (Table 3- D4-D5). Furthermore, the addition of this interaction term causes a diminution in the strength of the effects of all of the above predictors. This indicates that new friends who are cannabis users have a significant influence on behaviour, and that the influence of friends' cannabis use overall depends on the proportion of friends who are new to ego's friends and use cannabis.

(INSERT TABLE 3 ABOUT HERE)

Post-hoc analysis: Discrete influence from reciprocating and non-reciprocating friends

The strong interaction effect of *reciprocity X friends' cannabis use* suggests that behavioural influence is not necessarily weighted equally across ego's friends. To explore this more fully, effects were modelled from mutually exclusive groups of school peers, using discrete prevalence indices, along the lines suggested with respect to discrete modelling of friends and non-friends in Moriarty, McVicar and Higgins (Moriarty et al., 2012). This approach is used to assess the relative influence of mean cannabis use among friends who reciprocate ego's friendship nomination versus mean cannabis use among those who do not.

Initially, the wave 3 cross-sectional OLS model is augmented such that two separate terms representing the effect of each group's cannabis use prevalence. This model is then retested using the fixed effects approach using longitudinal values for both groups' cannabis use prevalence in waves 2, 3 and 4.

Table 4 suggests that both groups appear quite influential where the average behaviour of either group is entered as a stand-alone predictor. However, when both terms are entered together, there is a diminution in the size of the coefficient for non-reciprocating friends' cannabis use. When the individual fixed effects estimator is used, the coefficient for reciprocating friends' cannabis use falls to circa 0.24. The fact that this estimate of the effect of reciprocating friends' behaviour is at over

twice the magnitude of that of non-reciprocating friends is further support for the intensity hypothesis: friends at greater proximity and with whom more intense relationship exist exert a greater influence. However, it is also noteworthy that the behaviour of non-reciprocating friends remains statistically significant in all models. What is more, the two coefficients in this model sum to a value which resembles the overall effect estimated for friends' use using fixed effects in Table 3. This suggests that, while reciprocating friends are the dominant influence within the friendship cluster, the behaviour of non-reciprocating friends also makes up a valid component of the peer effect from friends' use.

(INSERT TABLE 4 ABOUT HERE)

Discussion

This paper underlines the value of integrating various approaches and outlooks on social networks and friendship clusters when considering the influence of peers on drug use behaviours and decisions. This represents an early attempt, using highly amenable data, to account simultaneously for behavioural and structural peer effects. The availability of longitudinal data covering a key developmental period of adolescence renders the estimates presented highly plausible estimates of the underlying causal effect. The novelty of these results is increased by the inclusion of post hoc analyses in which discrete behavioural influence of reciprocating and non-reciprocating friends are modelled separately within each model, a novel strategy for examining the intensity hypothesis.

Results suggest that network position and cluster structure have some direct effect on behaviour, though the actual behaviour of friends appears, from interaction effect models, to be the main driver of peer effects. Negative associations were found between cannabis use and both reciprocity from nominated friends and transitivity of nominations to cluster members. This suggests that being more embedded within a social group and experiencing greater group cohesion at the cluster level are protective factors against drug use during the age period observed. No curvilinear effects were apparent from the inclusion into the model of a squared terms for any of the cluster parameters.

Therefore these findings more closely corroborate the risk to social isolates posited by Ennett and Bauman (1993), rather than the risk identified by Henry and Kobus (2007) to those positioned between isolation and centrality. Note however that participants in the latter study were 16 years old and thus older than participants in both the current study and that of Ennett and Bauman. Henry and Kobus accept in their discussion that the risk to peripherals may develop in later adolescence. While those residing “in between” group attachment and total isolation may be at greater risk in later adolescence, the results presented here suggest that those peripheral to clusters or in clusters with little internal cohesion were most likely to use cannabis.

The interactive effects of friends’ cannabis use and transitivity of nominations illustrates most clearly the complex dynamic between structural and behavioural effects. The main effect for transitivity on cannabis use is negative, suggesting cannabis use is less likely where friends nominate on another more often. This relationship between cannabis use and lower transitivity coheres strongly with Grannovetter’s *Strength of Weak Ties* (1973). Clusters with higher transitivity of nominations are those which have fewer weak ties and are therefore more “closed”. Participants whose clusters had lower transitivity may be exposed to a wider sphere of influences across the overall network and may have more means of obtaining information about drug use and supply. However, the interaction between transitivity and friends’ mean cannabis use suggests that friends’ cannabis use is more influential and salient for ego when ego’s friends form a tightly-knit cohesive cluster. Therefore the main effect of cluster structure needs to be distinguished from the interaction effect. Drug use prevalence being equal, greater cohesion is protective against drug use. However, if drug use is more prevalent within the group, then greater cohesion makes members more likely to follow suit.

Estimates of the relative behavioural influence of reciprocating and non-reciprocating friends lend further support to the intensity hypothesis, that influence is greater where friendships are more intense. The behaviour of a reciprocating friend is more observable to ego because they spend a

greater amount of time together. Also, through the discourse within friendships, ego will come to know about their reciprocating friends' behaviours better than through discourses with a grademate whom they admire from afar. Ego also has more to lose from having their behaviour differ from a reciprocating friend than they do from a non-reciprocating one, as a closely-held friendship is potentially at stake if ego does not conform. If ego's drug use does differ from their friend's, there is more scope to purposely influence ego to change their behaviour if the friendship is reciprocal. However, this result also demonstrates some influence from friends who do not reciprocate. Whereas the former effect may represent one type of direct peer influence, the latter may represent a more aspirational mechanism whereby individuals try to "attain" friendships through mimicry of admired others.

Another significant contribution of the longitudinal dimension of this research that it enables comment on the extent to which homophilic selection augments peer effect estimates. Because individuals befriend others with similar traits and interests, an association between ego's behaviour and friends' behaviour may represent the combined effects of peers influencing behaviour and of individuals selecting drug using peers as friends. In the longitudinal model, the "Turnover X Cannabis Use" interaction term reflects the proportion of friends who were newly nominated and had used cannabis in the previous year. Other authors have suggested that selection of cannabis using peers accounts for approximately half of the association between ego's behaviour and peer behaviour (Kirke 2006, Kiuru et al. 2010). If this were to hold in the current model, the peer effect would be moderated to a much greater degree by the inclusion of this parameter. It is clear from both interaction models that the behaviour of new friends has a significant effect, but that overall friends' cannabis prevalence continues to be a significant factor.

Additionally, the independent effect on cannabis use of "turnover", or the proportion of new friends named is of importance. This showed cannabis use to be more likely in more volatile network groups. This should be considered alongside main effect for transitivity. There is mounting evidence

that being in an insecure position at the margins of friendship clusters, or having friends who do not share cohesive bonds with another are risk factors for the onset of drug use, as attested by Ennett (2006); Henry and Kobus (2007) and the current study. These marginal individuals may use drugs to impress and court new friends, or as a reaction to stress or rejection. Alternatively, their befriending may be linked to supply and the need to make new contacts. This finding gives additional support to Granovetter's *Strength of Weak Ties* (1973).

Limitations

No exclusion criteria were put in place for schools with low response rates, given the emphasis on egocentric networks rather than complete networks. No individuals excluded from analysis on the basis of the response rate within their friendship groups. This presents a possible limitation in that absence from school or non-completion may be associated with either drug behaviour or sociability.

A further limitation which this study shares with much of the literature is that only a selected subset of peers is observed. Missing from the data is any representation of the type of ties ego has outside of the school grade boundary, and behaviour in those alternative peer reference groups.

Furthermore, there is no way of verifying how friendship nominations map onto day-to-day interactions with peers. Even if self-reported friendship intensity were available, it would be very difficult to model alongside peer behaviour without creating further problems of endogeneity.

Implications

Recent education literature has seen a move towards “data-driven interventions”, whereby academic and behavioural interventions at the individual and school level are triggered by the emergence of data collected in real time, such as critically low test scores (Lane 2007, Carlson, Borman & Robinson 2011). The current study suggests that continuous monitoring of young people's sociability and interaction quality in school could usefully prompt the school to issue preventative information on substance use. On a wider level, the mounting evidence of behavioural influence

from peers' drug use could form the basis of school-level indices whereby if prevalence of early drug use initiation passes a threshold, that school is identified as at risk of rapid further "contagion".

Such innovation would likely be enhanced by adding further depth to social network-based research and further testing its validity. One promising avenue is the use of Ecological Momentary Assessment (EMA; Shiffman et al., 2008). This method requires participants to report on phenomena such as health, mood, behaviours and, in this instance, social interactions, in real time using devices such as electronic diaries. By incorporating this technique into a follow-up study alongside a replication of the survey-based nomination field, researchers could obtain two important pieces of evidence: how often is there actual interaction between ego and each of their nominated friends (and, by extension, how does this day-to-day intensity moderate their influence on ego's behaviour); secondly, what proportion of social interaction is with individuals outside of the boundaries of school.

Furthermore, studies such as this suggest a dividend to successful intervention whereby preventing one young person's early cannabis uptake has a multiplier effect on those around them.

Additionally, intervention can be multi-faceted: increasing young people's sociability and quality of bonds with classmates may also reduce their exposure to early cannabis use.

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Figure 1: Empirical modelling of behavioural and structural peer effects

	0	1	2	3	4	5
A Cross-Section: Network Parameter Models	Reciprocity Transitivity Convergence					
B Cross-Section: Mixed Behavioural and Network Models	Peer Cannabis Use					
C Cross-Section: Network-Behaviour Interaction Models	Peer Cannabis Use					
	Reciprocity X Transitivity	Transitivity X Peer Cannabis	Reciprocity X Peer Cannabis Transitivity X Peer Cannabis	Transitivity X Peer Cannabis Reciprocity X Peer Cannabis Reciprocity X Transitivity	Peer Cannabis X Reciprocity X Transitivity	
D Longitudinal Fixed Effects: Network-Behaviour Interaction	Peer Cannabis Use					
	Reciprocity Transitivity Convergence	Turnover Reciprocity Transitivity Convergence	Reciprocity X Peer Cannabis Turnover Transitivity	Transitivity X Peer Cannabis Reciprocity X Peer Cannabis	Transitivity X Peer Cannabis Reciprocity X Peer Cannabis Turnover X Peer Cannabis	Peer Cannabis X Reciprocity X Transitivity Turnover X Peer Cannabis

Table 1: Friends' cannabis use, reciprocity, transitivity & convergence as independent predictors of cannabis use

Peer Effect (Friends' mean)	Reciprocity	Transitivity	Convergence	Nobs	R-squared
-	0.030 (0.027)	-	-	4206	0.166
-	-	-0.087*** (0.037)	-	4206	0.168
-	-	-	-0.052 (0.032)	4206	0.167
-	0.087***	-0.129*** (0.041)	-0.019 (0.037)	4206	0.169
0.579*** (0.030)	-	-	-	4206	0.240
0.572*** (0.030)	0.057*** (0.025)	-	-	4206	0.243
0.567*** (0.030)	-	-0.062** (0.031)	-	4206	0.242
0.567*** (0.030)	-	-	- 0.020 (0.031)	4206	0.241
0.567*** (0.030)	0.126*** (0.028)	- 0.140*** (0.040)	0.005 (0.036)	4206	0.245

*** p < 0.01; ** p < 0.05; * p < 0.1

Table 2: Cross-section interaction models: Cluster parameters X Mean friends' cannabis use

Model	Behavioural effect: friends' mean cannabis use	Reciprocity	Transitivity	Reciprocity * Transitivity	Reciprocity * Friends' Cannab	Transitivity * Friends' Cannab	Reciprocity * Transitivity * Friends' Cannab	Nobs	R-squared
C0	0.571** (0.045)	0.024 (0.056)	-0.256** (0.088)	0.193 (0.103)	-	-	-	4206	0.246
C1	0.580** (0.040)	0.105** (0.029)	-0.117** (0.041)	-	-	-0.020 (0.093)	-	4206	0.247
C2	0.458** (0.069)	0.003 (0.036)	-0.200 (0.109)	-	0.316** (0.102)	-0.059 (0.042)	-	4206	0.249
C3	0.450** (0.069)	-0.080 (0.062)	-0.209* (0.088)	0.196 (0.106)	0.318** (0.101)	-0.182 (0.108)	-	4206	0.249
C4	0.594*** (0.029)	-0.006 (0.070)	-0.082 (0.100)	0.028 (0.121)	0.097 (0.187)	-0.543* (0.156)	0.498 (0.337)	4206	0.250

** p < 0.01; * p < 0.05; Cross-sectional Ordinary Least Squares regressions (year 3), controlling for gender, age, household composition, educational ambition, affluence and school; Coefficients presented as "Beta (Standard Error)"

Table 3: Fixed Effects (Balanced Panel) : Mean cannabis use X network parameters

Model	Behavioural effect: friends' mean cannabis use	Reciprocity	Transitivity	Friendship Turnover	Reciprocity * Trans	Reciprocity * Friends' Cannab	Transitivity * Friends' Cannab	Reciprocity * Transitivity * Friends' Cannab	Turnover * Friends' Cannabis	N Obs (People)	R-squared
D0	0.463** (0.022)	0.035 (0.022)	-0.047 (0.026)	-	-	-	-	-	-	10472 (4213)	0.210
D1	0.373** (0.023)	0.029 (0.021)	-0.029 (0.026)	0.160** (0.013)	-	-	-	-	-	10472 (4213)	0.204
D2	0.211** (0.048)	-0.036 (0.025)	-0.031 (0.026)	0.163** (0.013)	-	0.238** (0.062)	-	-	-	10472 (4213)	0.203
D3	0.180* (0.084)	-0.087* (0.037)	-0.114** (0.053)	0.111** (0.016)	-	0.161 (0.114)	-0.148 (0.167)	-	-	10472 (4213)	0.201
D4	0.105 (0.059)	-0.114*** (0.037)	-0.156** (0.052)	0.111** (0.016)	-	0.271** (0.072)	0.022 (0.083)	-	0.197** (0.053)	10472 (4213)	0.201
D5	0.180* (0.084)	-0.087* (0.037)	-0.114** (0.053)	0.111** (0.016)	0.105* (0.052)	0.161 (0.114)	-0.148 (0.167)	0.226 (0.194)	0.197** (0.053)	10472 (4213)	0.201

** p < 0.01; * p < 0.05; Fixed effects (year 2-4), controlling for non-stable confounders: household composition, educational ambition, affluence and school; Coefficients presented as "Beta (Standard Error)"

Table 4: Reciprocating friends', non-reciprocating friends' influence

	Reciprocating friends' cannabis use, coefficient (robust standard error)	Non-reciprocating friends' cannabis use, coefficient (robust standard error)	Nobs	R-squared
OLS, school dummies: Reciprocating only	0.417** (0.025)	-	4206	0.226
OLS, school dummies: Non-reciprocating only	-	0.138** (0.027)	4206	0.166
OLS, school dummies: 2 groups	0.404*** (0.026)	0.081** (0.022)	4206	0.235
Fixed Effects: 2 groups	0.230** (0.022)	0.086** (0.014)	9876 (3881)	0.170

** p < 0.01; * p < 0.05; Cross-sectional Ordinary Least Squares regressions (year 3), controlling for gender, age, household composition, educational ambition, affluence and school; Fixed effects, controlling for household composition, educational ambition, affluence and school